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POPULATIONS OF TRAP-NESTING WASPS NEAR A MAJOR SOURCE OF FLUORIDE EMISSIONS IN WESTERN TENNESSEE

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Abstract.—Trap-nesting wasps were collected from eight sites at distances of from 1.2–33.0 km from an aluminum reduction plant in western Tennessee. The sites had similar topographies, soils, and vegetation, but differed in their exposure to fluoride, which was emitted in large quantities from the plant. It was postulated that if fluoride emissions had greatly changed the insect community then relative densities of their predators would have varied accordingly. However, the degree of fluoride pollution was unrelated to the relative densities of the wasps and to the number of cells provisioned with prey. *Monobia quadridens, Trypargilum clavatum,* and *T. lactitarse* were found to have two complete generations in western Tennessee. *Trypargilum collinum rubrocinctum* has at least two generations, and *Euodynerus megaera* probably has three generations. Six other wasp species and a megachilid bee were also collected.

The effect of an environmental contaminant, such as fluoride, on insect communities is difficult to evaluate because of the diversity of insect species and the natural fluctuations in their populations. Levin (1982) and Moriarty (1983) suggested a need for toxicological studies on the functioning of ecosystems, rather than just investigations on the effects of chemicals on individuals or on populations of particular species. Our approach was to study "trap-nesting" wasps, described by Krombein (1967), at several sites having a gradient of exposure to fluoride. If the composition of an insect community were greatly changed because of environmental contamination, it would be reasonable to expect changes in the populations of these predators. Woodwell (1970) suggested that "obligate carnivores high in the trophic structure, are at a disadvantage because the food chain concentrates the toxin and, what is even more important, because the entire structure beneath them becomes unstable." Although this statement may be an oversimplification, since many ecological and physiological factors influence the movement of environmental contaminants in food chains, the choice of a group of predators for studying the effects of fluoride seems reasonable.

The life histories and prey of the species studied here are known (Krombein, 1967). They belong to several families, but have similar nesting habits. All seek out holes in wood, where they construct cells, partitioned with soil or debris. Cells are provisioned with prey, an egg laid, and the cells and hole sealed. Adults emerge either a few weeks after the egg is laid or the following year, after the larvae have overwintered. These wasps can be readily studied because they can be attracted to wooden blocks that have holes drilled in the ends, called "trap-nests." In addition to providing information on species distributions, life histories, prey, nesting habits, and parasites, the trap-nesting technique seems to have the potential for comparing relative densities of wasps at different sites. The technique may prove suitable for studying community indices, such as species diversity.

Our intent was to determine whether populations of trap-nesting wasps were reduced at sites greatly polluted with fluoride. The study was conducted concurrently with studies by the Patuxent Wildlife Research Center on the effects of fluoride on songbirds and on the decomposition of the litter horizon. We also hoped to gain information on the life histories of these wasps in Tennessee.

METHODS

Eight sites were selected at various distances from the Consolidated Aluminum Company's (CONALCO) aluminum reduction plant on Kentucky Lake, in Humphreys County, Tennessee. The plant emits more than 3000 tonnes of fluoride per year when operating at peak capacity; from 1980 to 1984 the plant operated at about 25–50% of capacity and the fluoride emissions were reduced proportionally (Tennessee Valley Authority, unpublished data). Compared to emissions at other industrial plants in the United States these emissions are very high. Sites 1, 2, and 5 were in Humphreys Co.; 3, 4, and 6 in Benton Co.; and 7 and 8 in Henry Co. Sites 1–8 were located at 1.2, 1.4, 3.6, 4.4, 4.5, 8.8, 32, and 33 km from the plant (Fig. 1). From the study of the effects of fluoride on the decomposition of litter we know that the acid-extractable fluoride concentrations in the litter decreased progressively with the distance of the sites from the plant (Sites 1–8; 695, 440, 107, 102, 50, 46, 16, 12 mg/kg F). Sites 1 and 2 should be considered very contaminated. All sites were on upland ridges or slopes, had similar soils, and were dominated by a mixture of red and white oaks (*Quercus* spp.) and shagbark hickory (*Carya ovata* [Mill.] K. Koch). The sites were selected so that the only apparent ecological difference was the exposure to the emissions from the aluminum reduction plant.

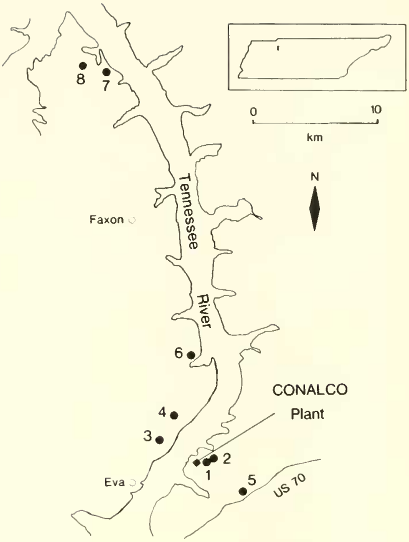

Fig. 1. The 8 sampling sites located at distances of from 1.2 to 33 km from the CONALCO plant in northwestern Tennessee.

In April 1984 traps were set out in a stratified random manner. At each site we laid down a 100-m transect with six predesignated randomly located points, one in each of six equal lengths of the transect. Each randomly selected point that fell within 5 m of another point was replaced by another randomly selected point. We selected the tree closest to each point and mounted a platform to hold each set of traps about 1.5 m high. The traps were cut from clear spruce (2.7 × 2.7 × 16.0 cm) and had bore diameters of 12.7 mm ($\frac{1}{2}$ inch), 6.4 mm ($\frac{1}{4}$ inch), 4.8 mm ($\frac{3}{16}$ inch), or 3.2 mm ($\frac{1}{8}$ inch), as described by Krombein (1967). The three largest borings were 15.0 cm deep, and the smallest was 6.0 cm deep. The traps were set out in groups of six, one each of the largest and smallest sizes, and two each of the intermediate sizes. They were held to-

Table 1. Occurrence of wasps and bees in wooden trap-nests at eight sites located at different distances from an aluminum reduction plant in western Tennessee.

Species of Wasp or Bee	No. Traps Used by Species at Sites 1–8								
	1	2	3	4	5	6	7	8	Total
Eumenidae									
Stenodynerus krombeini Bohart	0	0	0	1	0	0	0	0	1
Parancistrocerus pedestris (Saussure)	0	0	0	0	0	0	0	2	2
Euodynerus foraminatus (Saussure)	0	2	0	0	0	0	0	0	2
Euodynerus megaera (Lepeletier)	0	2	0	3	3	1	0	2	11
Monobia quadridens (Linnaeus)	0	3	0	2	0	5	5	1	16
Pompilidae									
Dipogon sayi Banks	0	0	1	0	0	0	0	0	1
Sphecidae									
Podium rufipes Fabricius	0	0	0	0	0	0	0	3	3
Isodontia auripes (Fernald)	0	0	0	0	3	0	0	4	7
Trypargilum clavatum (Say)	5	2	8	2	3	1	3	1	25
Trypargilum lactitarse (Saussure)*	5	0	0	1	7	2	3	0	18
Trypargilum collinum rubrocinctum (Packard)	2	6	1	1	2	0	4	1	17
Megachilidae									
Osmia pumila Cresson	0	0	2	0	0	0	0	0	2
Unidentified	1	0	1	3	1	3	2	0	11
Total occurrences	13	15	13	13	19	12	17	14	116

* Cited as *T. striatum* (Provancher) (Krombein, 1967), a junior synonym.

gether and attached to the platform with rubber bands.

About once every three weeks, from May 13 to September 13, traps with nests were collected and replaced by empty ones. The open end of the collected traps was wrapped in a nylon screen and secured with a rubber band to prevent the emerged wasps from escaping. Some of the larger wasps chewed through the nylon, so wire screens were added to some of the traps. To break the diapause of larvae that did not emerge in 1984 we moved the traps with closed cells to an unheated greenhouse on October 5, and brought them back inside on March 3. Traps with cells that were still closed by August 1985 were opened. Emerging adults were keyed to genus or to species (when keys were available), and then compared with specimens in the National Museum of Natural History, Washington, D.C. Nomenclature (Table 1) follows Krombein et al. (1979). For some species the architecture of the nest (*Isodontia auripes*) or the shape of the cocoon (*Trypargilum*) was distinctive enough to permit identification. Wasps from about 10% of the traps could not be identified; these individuals had been parasitized, had died for other reasons, or had escaped from the traps.

Spearman rank correlation coefficients (Conover, 1980) were used to determine whether the distances of the sites from the plant were related to either the number of traps used or the number of cells provisioned per site. Additional analyses were planned only if the correlation coefficients were significantly different from zero.

RESULTS AND DISCUSSION

Fluoride emissions seemed to have no discernible effect on the populations of trap-nesting wasps. The number of trap nests used by wasps was about the same at each site, varying only from 12 to 19 (Table 1). An average of 14 traps was used at sites 1 and 2, which is close to the average of 14.7 for the six sites farther from the plant. The number of traps used was not significantly correlated with the distance of the sites from the plant (Spearman rank correlation coefficient = 0.00, $P > 0.05$). Sites 1 and 2 were exposed to extremely high concentrations of fluoride, but we collected 6 of the total of 11 species of wasps at one or the other of these sites. We cannot rule out the possibility that populations of particular species of wasps have been reduced or eliminated close to the plant. However, when all trap-nesting wasps are considered as a unit we conclude that the populations are just as high close to the plant as far from it.

The numbers of provisioned cells per site provide a second way of evaluating the effects of fluoride on trap-nesting wasps. They were as follows: site 1–43, site 2–39, site 3–61, site 4–41, site 5–81, site 6–37, site 7–69, site 8–44. These numbers were not significantly correlated with distances of the sites from the plant (Spearman rank correlation coefficient = 0.26, $P > 0.05$). Many invertebrate prey were required to support the wasp populations. For example, wasps of the three species of *Trypargilum* we collected provision their cells with means ranging from 11 to 16 spiders (Krombein, 1967). These species provisioned an average of 3.6 cells per trap in Tennessee. Each spider requires many prey, so we estimate that the 60 *Trypargilum* collected in the study were dependent on many thousands of prey. *Dipogon sayi* also preys on spiders. All of the eumenids prey on caterpillars, *Podium rufipes* preys on cockroaches, and *Isodontia auripes* preys on Orthoptera (Krombein, 1967).

Field studies relating fluoride to populations of other kinds of insects have been reviewed by Alstad et al. (1982). Populations of some herbivores, such as the pine bud moth (*Exoteleia dodecella*), increased in areas polluted with fluoride, presumably either because the host plants were weakened or because the numbers of parasites or predators were suppressed. Populations of silkworms, honeybees, some bark beetles (*Pityokteines*) and the European pine shoot moth (*Rhyacionia buoliana*) were shown to be lower than normal in areas polluted with fluoride. In a study of invertebrates collected near an aluminum reduction plant, scavengers tended to have the highest concentrations of fluoride, followed by predators, omnivores, and herbivores (Buse, 1986). There are conflicting opinions on whether fluoride is accumulated in food chains (Alstad et al., 1982). Hymenoptera as a group tend to accumulate relatively high concentrations of fluoride, compared to other kinds of insects (Dewey, 1973). However, the main route of exposure (respiration, food, grooming) of fluoride to Hymenoptera has not been identified (Alstad et al., 1982), and the trap-nesting wasps may have a much lower exposure to flouride than species such as honeybees, which forage for pollen.

The species we obtained had all been collected previously in trap-nests (Krombein, 1967). Five of the species nested frequently enough to permit generalization about their life histories in Tennessee. *Monobia quadridens, Trypargilum clavatum,* and *T. lactitarse* have two complete generations, the first emerging mainly in August, and the second the following spring. *M. quadridens* and *T. lactitarse* selected the 12.7 mm borings almost exclusively, and *T. clavatum* showed a preference for the 6.4 mm borings but selected some of the 4.8 mm borings. These species probably have a single generation in northern states, but two generations in Florida and North Carolina (Krombein, 1967). The seasonal changes in the populations of *Trypargilum collinum rubrocinctum* were less clear, and all that we could conclude was that there were at least two generations per year. This species selected the 4.8 mm borings almost exclusively. *Euodynerus megaera* is bivoltine in North Carolina (Krombein, 1967). Several traps collected from Tennessee in June had wasps emerging in July, and several traps collected in July and August had wasps emerging in August or September. None of the wasps emerged in the spring, which suggests that there was a third generation in the fall that we did not obtain. This species showed a strong preference for the 6.4 mm borings.

About 13% of the traps were parasitized by Diptera, Encyrtidae, or other parasites. The mutillid wasp, *Sphaeropthalma pensylvanica* (Lepeletier), parasitized nests of *T. clavatum* and *T. lactitarse,* as previously reported (Krombein, 1967), but it also parasitized a nest of *Isodontia auripes.*

In evaluating the trap-nesting technique for studying the effect of contaminants on insect populations we find two drawbacks. Combining all of the wasps yields large sample sizes, but we note that the species feed on prey belonging to different food chains. Generalizing requires disregarding many of the important differences between species, if we are to examine the functioning of the whole insect community. Also, although we assume that the numbers of wasps collected in the traps vary with relative densities, there may be other ecological variables, such as the number of suitable natural holes present, that would make the traps more attractive to wasps at some sites than at others.

The advantage of the trap-nesting technique is that the results are relevant to the community. Populations of forest insects are frequently variable, making it difficult to relate a pollutant to changes in a population (Alstad et al., 1982). Unless all of the populations of individual species vary in synchrony with each other, the combined populations of several species should be more stable and easier to evaluate than the populations of individual species. If the species have overlapping niches then the functioning of the community may remain similar even if the populations of the species change relative to each other. The technique also enables sampling of populations over their entire season. If the populations of trap-nesting wasps were reduced at particular sites then it would be reasonable to examine community variables, such as species diversity.

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